The ecological restoration of Otamahua/Quail Island 2. The vascular land flora and vegetation

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Abstract

The plant species present on Otamahua/Quail Island 1976-1999 are grouped according to origin, specifically identifying indigenous and introduced taxa. The known vascular plant flora for this period consists of 357 species. Taxa believed to be descended from ancestors truly indigenous to the island include 7 tree species, 18 shrubs, 7 vines, 28 monocotyledon and 49 dicotyledon herbs, and 12 ferns. Additional indigenous taxa from the Banks Peninsula region, planted on the island up to the beginning of 1998, include 8 tree species, 3 shrubs and 1 large monocotyledon herb. A further 10 tree, 2 shrub, and 4 vine indigenous species of Banks Peninsula provenance were planted during 1998 and 1999. Planted taxa indigenous to New Zealand, but not to Banks Peninsula, include 4 small trees and 1 shrub.

Among the taxa foreign to the New Zealand flora that have been planted on the island, or that have otherwise immigrated accidentally through human agency, or by natural means, are 29 tree species, 19 shrubs, 3 vines, 46 monocotyledon herbs (mostly grasses), 120 dicotyledon herbs and 2 ferns. Localities, habitats and relative abundance are noted for each species. There appear to have been losses of some species since 1976 (some through deliberate removal). Recent gains of some introduced species apparently have occurred by natural means.

The main kinds of terrestrial vegetation, based on physiognomic/floristic criteria, are: grassland, fernland, shrubland, treeland and open communities of cliff faces, rock outcrops, talus and beaches. Wetland vegetation is sparse, but distinctive.

Keywords: flora - true indigenes - planted indigenes - introduced species - immigration - naturalisation - vegetation type.

Introduction

Almost 150 years have passed since the first European farm was established on Otamahua, in 1851. From the sparse mid 19th century records (Ward 1851) it appears that, then, the main plant cover of the island was short tussock grassland with associated herbs, and a scattering of shrubs and bracken fern, but very few trees. All were indigenous. Now the flora and vegetation of the island are dominated by species introduced to New Zealand from other parts of the world, particularly Europe and North America. Evergreen conifer and deciduous angiosperm woodland and dense sward grassland form most of the cover and native plants are relatively inconspicuous. Nevertheless many indigenous plant species are present, reproduce themselves and in some places

are locally abundant.

Genet & Burrows (1998, 1999) suggested that Otamahua's vegetation before first Maori settlement, many centuries ago, would have been extensive forest and scrub. As evidence for the view that the island was once well wooded, they noted the occurrence of indigenous woodland on similar sites elsewhere on Banks Peninsula and in North Canterbury. They also pointed out that gradual natural redevelopment of such woodland is occurring on Otamahua, and that many native trees and shrubs, planted on the island in the 1980s, have done well and are now themselves reproducing. These observations have provided the motivation for attempting the ecological restoration of Otamahua, the first stage of which is the extensive planting of a considerable range of indigenous woody species (Genet & Burrows 1999).

In this account the vascular plant species already established on the island up to mid 1999 are listed (Table 1) and categorised in various ways. Species planted in 1998 and 1999 are considered separately (Table 2).

Among the indigenous species those thought to be derived from ancestors that were already present earlier than 1851 are distinguished from some that have been planted (or in rare cases may have immigrated of their own accord) in recent decades. The introduced species foreign to the New Zealand flora, or to Banks Peninsula, are classed as either having been deliberately planted (or probably so); having probably arrived accidentally, by human agency; or having very likely arrived as a result of transport by natural vectors, between 1851 and the present. Planted species which have subsequently become naturalized (i.e. are reproducing and spreading of their own accord) are identified.

Evidence is adduced for the relatively recent arrival of some plant species on the island, accidentally through human agency, or by natural means. The apparent loss and in some cases deliberate removal of some other species from the flora are also noted. A brief account of the main kinds of vegetation on the island discusses the most prominent species in each physiognomic/compositional class. Fig. 1 includes placenames referred to in text and tables, and the more extensive areas of distinctive vegetation.

Vascular plant flora

The floristic checklist (Table 1) is compiled from: Sissons (1976) (planted or naturally occurring trees and shrubs); Chapman (1978); Molloy (1979) (indigenous and introduced naturalised and planted species); Wilson (1986-88), Meurk (1997) (unpublished lists of indigenous and introduced naturalised species); Wilson (1992), and Burrows (1997-99) (collections of indigenous and introduced species, planted and naturalized, with checks of certain taxa by H.D.W.). Vouchers were placed in the National Herbarium (CHR, Landcare Research, Lincoln) by H.D.W. and, for a few less well-known species, in the Plant and Microbial Sciences herbarium (CANU), University of Canterbury, Christchurch, by C.J.B. Nomenclature for plants in this article follows Allan (1961), Moore & Edgar (1970), Healy & Edgar (1980), Connor & Edgar (1987), Webb *et al.* (1988), Brownsey & Smith-Dodsworth (1989), and, for grasses not covered by Connor & Edgar (1987), citations in Wilson (1992, 1999) and Connor (1998).

In the checklist records from Sissons (1976) and Molloy (1979) are incorporated, with nomenclatural changes where appropriate. Only one taxon listed by Chapman (1978), *Coprosma rotundifolia,* was not seen by Molloy (1979). A few apparent errors of identification by Sissons are noted.

Origins of the present flora

True indigenes

Almost all of the taxa listed in Table 1, part A are believed to be derived from ancestors that were present before European settlement. An

indication of this from Maori tradition is the old name for the island, Te Kawakawa (Fournier *et al.* 1838) which applies to the shrub *Macropiper excelsum.* Jackson (1990) indicated that one specimen of this species occurs on the island. Sissons (1976) also recorded it. A recent search shows that the species (presumably the same individual) occurs beneath the north-eastern cliffs. A sapling and seedling derived from it are also present. Five individuals of the species, originating from Banks Peninsula stock, were planted near the visitor information centre (Fig. 1) during the winter of 1998 and another 36 in various places in 1999.

An April 1844 drawing by John Barnicoat of "Quail Island, Port Cooper", from the sea on the north side, shows the cliffs and a bare summit plateau. Small areas of what may be scrub are marked on part of the glacis beneath the cliffs. A drawing by the same artist, from above Rapaki, shows the head of Whakaraupo harbour, including the top of the island. No vegetation is depicted (reproductions in Maling, 1981, p.65).

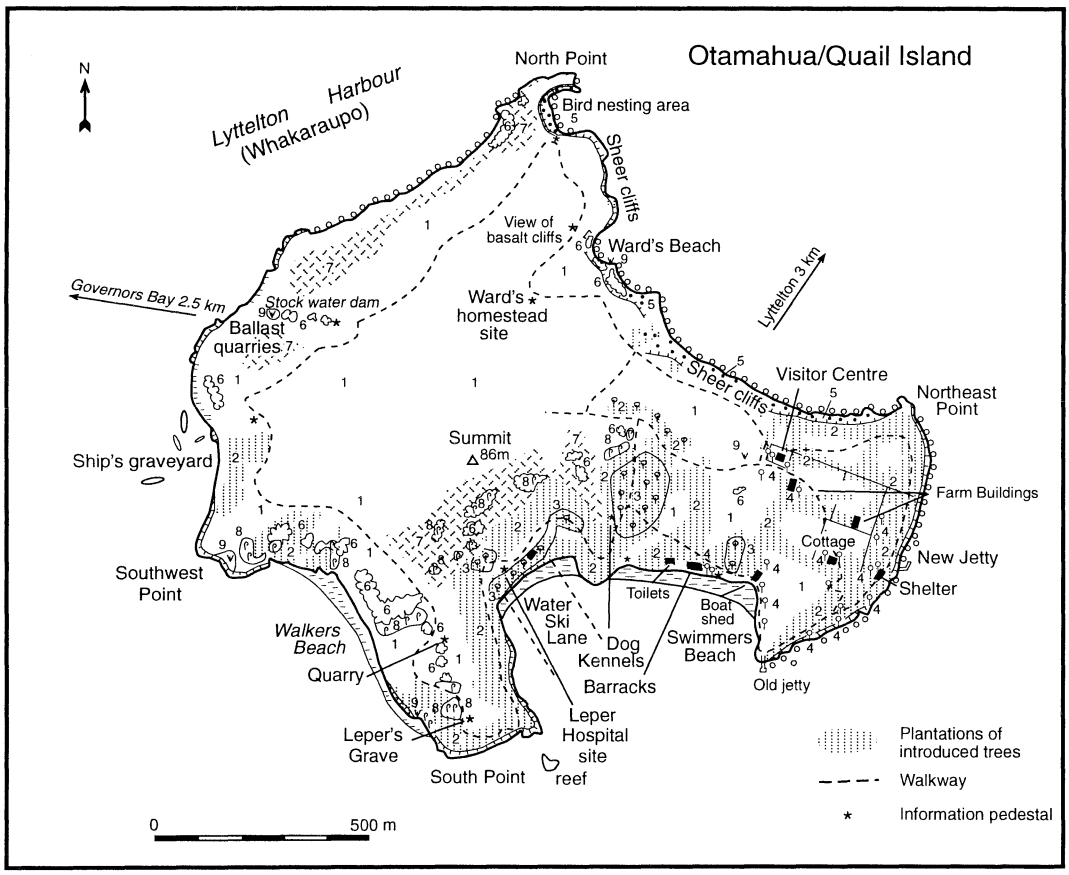
Edward Ward, who with his two brothers started the first farm on the island in 1851 (Ward 1851, p. 189), speaks of "grasses" and records the cutting of "aki aki" *(Olearia paniculata* or possibly *Dodonaea viscosa)* for firewood. In a drawing of the Ward's house by W. Holmes, in 1852 (Adams 1853), cabbage trees or ti-kouka *(Cordyline australis),* and a harakeke *(Phormium tenax)* plant are evident. The latter could have been planted, as it is small and growing alongside a turf fence. Silver tussock grass *(Poa cita)* must have been abundant on Otamahua but does not show clearly in the drawing. A survey map of the island prepared in 1907 shows a patch of "manuka" near the stock dam on the north-west side of the island (Jackson 1990, p. 57). The species is actually kanuka, *(Kunzea ericoides),* and, though the stand is old, it may not pre-date the Wards.

As it is unlikely that deliberate planting (or other kinds of immigration) of most of the rest of the indigenous angiosperm herbs, vines, shrubs, or ferns listed in Table 1, Section A have occurred since 1851 it is assumed that they are true indigenes, descended from lineages that have been present from time immemorial. Recent natural immigration of indigenous species is assumed for very few (Table 1). Most of the indigenous herbs are confined to relatively open habitats such as cliffs, rock outcrops, the shoreline and dry sites, where the competition from tall introduced grasses is reduced. Truly indigenous herbs or ferns recorded by Molloy (1979) but not seen during recent fieldwork are: *Carex* cf. *breviculmis, Potamogeton* sp., *Aciphylla suflabellata, Gingidia montana, Muehlenbeckia axillaris* and *Asplenium oblongifolium* (= *A. lucidum* in Molloy's list). Among the true indigenes 1 tree species, 3 shrubs, 1 vine, 23 herbs, and 4 ferns have been added to the flora during field work in the 1990s (Table 1).

Cabbage trees are relatively numerous on southern aspects and so are kanuka. Otherwise trees truly native to the island, broadleaf *(Griselinia littoralis),* mahoe *(Melicytus ramiflorus),* ngaio *(Myoporum laetum),* mapou *(Myrsine australis)* and kohuhu *(Pittosporum tenuifolium)* are represented by very few individuals. Most occur in protected moist sites beneath the north-eastern cliffs. Indigenous woody plants listed by Chapman (1978) or Molloy (1979) but not seen lately are *Coprosma rotundifolia* and *Myrsine divaricata.*

Planted indigenes

Several thousand indigenous woody specimens were placed on the island in the early 1980s, by Department of Lands and Survey staff. Many of the young plants were killed by rabbit and sheep browsing and only a few hundred survived to adulthood (Claire Findlay, pers. comm., Fig. 1). Most of the species that survive have given rise to new seedlings in the last few years (Table 1). All of these planted taxa inhabit natural stands around Lyttelton Harbour on sites similar to those present on Otamahua. They are assumed to have been part of the original woodland veg-



1 Grassland, mainly introduced species with scattered indigenous species on slopes and some shrubs and occasional trees
2 Introduced conifer woodland (+ some angiosperm species)
3 Introduced deciduous woodland (+ some evergreen angiosperms, conifers)
4 Planted indigenous woodland (1980s)
5 Introduced shrubland
6 Indigenous shrubland / vines
7 Indigenous shrubs scattered in introduced grassland
8 Bracken fern
9 Phormium
Cliff
Boulder beach
Shelly beach

Figure 1 Distribution of the vegetation cover, early 1998.

etation on the island before its deforestation, during the early period of Maori occupation.

Two adjacent karaka trees *(Corynocarpus laevigata)* are present on the summit plateau of Otamahua near a water storage tank. This species is thought to have been introduced to Banks Peninsula by Maori people, probably several centuries ago (Wilson 1999). Two small karaka trees were noted at the same site by Molloy (1979) so it appears that the trees, now quite gnarled, were planted not long before that date.

A few species indigenous to New Zealand or its outlying islands, but not to Banks Peninsula, were planted on Otamahua probably in the period between about 1940 and 1970 (Sissons 1976). These are noted in Table 1 among the "Introduced" species.

Species planted on the island in 1998 and 1999 as part of the new ecological restoration project (Genet & Burrows 1999) are listed in Table 2. A similar range of species to those planted in the early 1980s was put in in 1998, with some additions (Tables 1 and 2). Further variety was added in 1999. The plants are all lo-

Table 1 Vascular land checklist for Otamahua/Quail island (excludes species planted in 1998-1999 - see Table 2). Key: O, originally present (i.e. descendants of plants which were there from the time of Maori settlement); P, planted in the early 1980's or earlier; N, naturalised on Otamahua; 1, Species indigenous to New Zealand and present in Lyttelton Harbour Basin or nearby on Banks Peninsula are listed here, 2. Most species listed here are foreign to the New Zealand flora, 3, Species indigenous to New Zealand but not to Banks Peninsula; *, Location - Summ. - summit plateau, S, W etc - slopes or level sites below summit plateau; ** Habitats are not indicated for planted species unless they are naturalised. Lack of entry otherwise means that there is no information; (s), planted indigenous species for which new seedlings are evident; (R), may have immigrated naturally, recently, L, apparently lost from the flora between 1976 (Sissons) or 1979 (Molloy) and 1998), X, removed from the flora between 1976 (Sissons) or 1979 (Molloy) and 1998 (in a few cases the taxon may have been lost by natural means); +, Karaka occurs on Banks Peninsula but was probably introduced there by Maori, long ago; although whaririki occurs on Banks Peninsula it is rarely found at sea level - the few plants apparently were placed on Otamahua after 1979; ?, probably recorded in error; ! possibly accidentally or deliberately introduced from Australia in 19th Century; ( ) extensive root suckers, some appear to be independent; Abundance, common - hundreds to many thousands, mod. - moderately common - up to a few hundred, few - only a few tens observed, rare - less than ten observed; Record, 1 - listed by Sissons 1976, 2 - listed by Molloy, 3 - observed during recent fieldwork.

	Family	O	P	Location*	Specific Habitat**	Abundance	Record
A. Indigenous Species[1]							
Trees							
Aristotelia serrata wineberry	Elaeoc.		•	SE		few	3
Cordyline australis cabbage tree	Lomandr.	•	• (s)	S	loess	mod.	1,2,3
Corynocarpus laevigata karaka	Coryn.		•+(s)	Summ.(E)		two	1,2,3
Griselinia littoralis broadleaf	Grisel.	•	•	NE, SE	under cliff	few	2,3
Hoheria angustifolia houhi	Malv.		• (s)	SE		few	3
Kunzea ericoides kanuka	Myrt.	•	•	S, W	loess	mod.	1,2,3
Melicytus ramiflorus mahoe	Viol.	•	• (s)	NE, S	under cliff	six	1,2,3
Myoporum laetum ngaio	Myop.	•	• (s)	NE, SE	under cliff	mod.	2,3
Myrsine australis mapou	Myrs.	•	• (s)	SE		few	1,3
Pittosporum eugenioides lemonwood	Pitto.		• (s)	SE		mod.	3
P. tenuifolium kohuhu	"	•	• (s)	NE, SE	loess	mod.	2,3
Plagianthus regius manatu	Malv.		• (s)	SE		few	3
Podocarpus totara totara	Podoc.		•	SE		few	3
Pseudopanax arboreus five-finger	Aral.		•	SE		few	3
Sophora microphylla kowhai	Papil.		• (s)	SE		few	2,3
Shrubs							
Carmichaelia australis NZ broom	"	•		S, W, NE	loess	common	1,2,3
Coprosma crassifolia thick-leaved c.	Rub.	•		S, W	loess, rocky sites	common	2,3
C. propinqua mikimiki	"	•		S, W	loess	mod.	2,3
C. rhamnoides variable-leaved c.	"		•	S	under trees	one	3
C. robusta karamu	"	•	• (s)	S, NE	under cliff	mod.	2,3
C. rotundifolia round-leaved c.	"	• L		S			1
C. virescens green-seed c.	"	•		S, W	loess	few	2,3
Discaria toumatou matagouri	Rhamn.	•		S, W	loess, rocky sites	common	1,2,3
Hebe salicifolia koromiko	Scroph.		• (s)	S, E		few	3
H. strictissima Banks Pen. h.	"	•	• (s)	S, Summ. (E)	on cliff	mod.	2,3
Helichrysum lanceolatum niniao	Aster.	•		S	under trees	two	3
Leptospermum scoparium manuka	Myrt.	•	•	SW, S, E	loess	common, local	1,2,3
Macropiper excelsum kawakawa	Piper.	•		NE	below seepage	two	1,3
Melicytus alpina whare-karara	Viol.	•		S, W	loess	few	3
Myrsine divaricata weeping mapou	Myrs.	• L		S			1,2
Olearia avicenniifolia silver akeake	Aster.		•	S		few	3
O. paniculata golden akeake	"	•	• (s)	S, NE	on cliff	mod.	1,2,3
Plagianthus divaricatus salt marsh ribbonwood	Malv.	•		S, W, NE	beach	few	1,2,3
Solanum aviculare poroporo	Solan.	• ?L		?		?	1
S. laciniatum poroporo	"	•		S, W, Summ.	under trees, scrub	common	2,3

	Family	O	P	Location*	Specific Habitat**	Abundance	Record
Sophora prostrata dwarf kowhai	Papil.	•		NE	cliff top	one	3
Urtica ferox ongaonga	Urtic.	•		S, W	under scrub, trees	mod., local	2,3
Vines							
Calystegia tuguriorum NZ bindweed	Convolv.	•		S, W, NE	rocky sites	mod.	2,3
Clematis afoliata leafless c.	Ranunc.	•		W	rocky sites	rare	3
Muehlenbeckia australis pohuehue	Polyg.	•		S, W, NE	loess, rocky sites	common	1,2,3
M. complexa shrubby p.	"	•		widespread	loess, rocky sites	common	1,2,3
M. australis x *complexa* hybrid p.	"	•		S, NE	loess, rocky sites	few	3
Rubus schmidelioides hairy-leaved lawyer	Ros.	•		S	loess, rocky sites	few	2,3
R. squarrosus leafless lawyer	"	•		S	loess, rocky sites	few	1,2,3
Herbs							
Monocotyledons							
Arthropodium candidum dainty lily	Lomand.	•		SE	shaded rock crevice	rare	3
Carex cf. breviculmis grass sedge	Cyper.	• L				?	2
C. raoulii raoul's c.	"	•		S	under trees	rare	3
C. cf. *resectans* dryland c.	"	•		S, SE	under trees	rare	3
C. virgata swamp tussock	"	•		W, S	wet areas	mod., local	2,3
Cortaderia richardii toetoe	Poa.	•		S	damp gully	rare	2,3
Deyeuxia billardieri coastal d.	"	•		NE	rock ledges	rare	2,3
Dichelachne crinita plume grass	"	•		S, E	rock ledges	few	2,3
Eleocharis acuta sharp spike-sedge	Cyper.	•		stock dam	pond	mod.	2,3
Festuca actae blue fescue	Poac.	•		NE	seepage	few	3
Hypoxis hookeri yellow star	Hypox.	•		Summ.	rock outcrop	mod., local	3
Isolepis cernua coastal club sedge	Cyper.	•		NE	rock ledges, seepage	few	2,3
I. nodosa big club sedge	"	•		NW, NE, S	shore, cliffs	mod.	2,3
Juncus australis southern rush	Junc.	•		Summ.	swales	few	3
J. distegus slender rush	"	•		Summ.,S	damp sites	mod.	3
J. gregiflorus hard rush	"	•		Summ., stock dam	swales, pond	common	2,3
J. sarophorus glaucous rush	"	•		Summ.	swales	few	3
Lemna minor duck weed	Lemn.	•		NE	seepage	mod., local	3
Libertia ixioides NZ iris	Irid.	•		W	shaded rock	few	2,3
Luzula banksiana var. *orina* banks' woodrush	Junc.	•		S, W	rock ledges	mod.	2,3
Microtis unifolia onion orchid	Orchid.	•		S	loess, slips	mod.	2,3
Phormium cookianum whaririki	Phorm.		• +	S		three	3
P. tenax harakeke	"	•	• (s)	S	damp rock, loess	mod.,local	1,2,3
Poa cita silver tussock	Poa.	•		S, W, SE	mod. dry sites, loess	common	2,3
Potamogeton sp. red pondweed	Potam.	• L		stock dam	pond	?	2
Puccinellia stricta salt grass	Poa.	•		S, NE	salt marsh, seepage	few	2,3
Rytidosperma clavata "danthonia"	"	•		Summ.	dry sites, loess	common	2,3
Thelymitra longifolia sun orchid	Orchid.	•		S	basalt outcrop	few	2,3
Dicotyledons							
Acaena novae-zealandiae piripiri	Ros.	• !		S	grassland	common	2,3
Aciphylla subflabellata narrow-leaved a.	Apiac.	• L		W	short grassland	rare	2
Apium prostratum NZ celery (slender form)	"	•		S	strand	few	3
A. prostratum (stout form)	"	•		S, NE	strand, cliff	mod.	2,3
Chenopodium glaucum ssp. *ambiguum* coastal goosefoot	Chenop.	•		S, NE	strand	mod.	3
Convolvulus verecundus ssp. *waitaha* small c.	Convolv.	•		W, NE	short grassland	mod.	2,3
Cotula australis soldier's buttons	Aster.	• !		S, W, Summ.	under trees, short grassland	mod.	3
Cotula coronopifolia bachelor's buttons	"	•		S, NE	salt marsh, seepage	mod.	2,3
Crassula sieberiana rock succulent	Crassul.	•		widespread	rock outcrops, short grassland	mod.	2,3
Dichondra repens mercury bay weed	Convolv.	•		Summ., W, S	short grassland	common	2,3
Disphyma australe horokaka	Aizo.	•		NE, E	cliffs, rock outcrops	mod.	2,3
Einadia allanii allan's goosefoot	Chenop.	•		S, NE	cliffs	few	2,3
E. triandra redberry goosefoot	"	•		S, NW	cliffs	few	3
Epilobium billardierianum willow herb	Onagr.	•		W, NE	on rock, seepage	few	2,3
E. cinereum willow-herb	"	•		S, W	cliffs, scree	mod.	3
E. nummulariifolium willowherb	"	•(R)		Summ. (E)	beside building	rare	3

	Family	O	P	Location*	Specific Habitat**	Abundance	Record
Euchiton audax grey cudweed	Aster.	•		S, W	short grassland	few	2,3
E. gymnocephalus dark cudweed	"	•		S	under trees, grassland	few	3
E. involucratus creeping cudweed	"	•		stock dam	edge of pond	mod., local	3
Geranium microphyllum small-leaved g.	Geran.	•		S	short grassland	mod.	2,3
G. sessiliflorum namunamu	"	•		S	rock ledges	few	2,3
G. solanderi solander's storksbill	"	•		E	cliff	few	2,3
Gingidia montana aniseed	Apiac.	• L					2
Haloragis erecta toatoa	Halor.	•		S, W, NE	scrub margins	few	3
Helichrysum filicaule everlasting	Aster.	•		W	short grassland	few	2,3
Hydrocotyle heteromeria common h.	Apiac.	•		NE	seepage	few	3
H. moschata musky h.	"	•		S, W, E	short grassland	mod.	2,3
Hypericum gramineum grass h.	Hyper.	•		S	short grassland	few	3
Leptinella squalida bachelor's buttons	Aster.	•		S	damp sites, short grassland	mod.	2,3
Leucopogon fraseri patotara	Epacr.	•		Summ., E	rock outcrop	few	3
Linum monogynum NZ linen flax	Lin.	•		S, W, E	cliffs	few	2,3
Muehlenbeckia axillaris dwarf pohuehue	Polyg.	• L		W			1
Oxalis exilis yellow flowered o.	Oxal.	•		S, Summ.	short grassland	few	2,3
O. rubens reddish o.	"	•		W. Summ.	short grassland	mod.	3
Pelargonium inodorum scentless p.	Geran.	• !		Summ.	bare ground	few	3
Pseudognaphalium luteoalbum woolly cudweed	Aster.	•		NE	cliffs, scree	few	2,3
Rumex flexuosus NZ dock	Polyg.	•		S	damp sites, short grassland	rare	2,3
Samolus repens sea primrose	Primul.	•		NE	seepage	mod., local	2,3
Sarcocornia quinqueflora glasswort	Chenop.	•		S	salt marsh	mod., local	2,3
Senecio glomeratus NZ groundsel	Aster.	•		S	grassland, under trees	common	2,3
S. lautus (complex) shore groundsel	"	•		S, NE	rocks on shore	few	2,3
S. minimus fire weed	"	•		S	grassland, near trees	mod.	3
S. quadridentatus pekapeka	"	•		S, W, E	cliffs, rock outcrop	mod.	2,3
Sonchus kirkii puha	"	•		E, NE	cliffs, seepage	rare	3
Spergularia media sea spurrey	Caryoph.	• !		S, NE	salt marsh, seepage	few	3
Stellaria decipiens NZ chickweed	"	•		S	shaded rock	few	2,3
Tetragonia trigyna NZ spinach	Tetrag.	•		W, NW, S	cliffs, under trees	mod.	2,3
Vittadinia australis NZ v.	Aster.	•		S, Summ.	short grassland, rock	mod.	2,3
Wahlenbergia gracilis grass bluebell	Campan.	•		N	short grassland	mod.	2,3
Ferns							
Asplenium flabellifolium necklace fern	Asplen.	•		W, S	rock outcrop	mod.	2,3
A. oblongifolium shining spleenwort	"	• L		NE	rock	rare	2
A. richardii rock spleenwort	"	•		S, W	rock	rare	3
A. terrestre ground spleenwort	"	•		S	rock	few	2,3
Blechnum fluviatile stream hardfern	Blechn.	•		S	basalt outcrop	rare	3
B. penna-marina little hardfern	"	•		S	basalt outcrop	rare	2,3
Cheilanthes humilis rockfern	Pterid.	•		Summ.	basalt outcrop	mod.	2,3
Hypolepis ambigua pigfern	Dennst.	•(R)		S	in bracken	rare	3
Pellaea rotundifolia round-leaved fern	Pterid.	•		S	basalt outcrop	rare	3
Polystichum richardii dark shield fern	Dryopt.	•		S	rock, under trees	common	2,3
Pteridium esculentum bracken	Dennst.	•		S	loess	common	2,3
Pyrrosia eleagnifolia snake fern	Polypod.	•		W, NE	cliffs	few	2,3
B. Introduced Species[2]		P	N				
Trees							
Acer pseudoplatanus sycamore maple	Acer.	•	• X	S			1,2
Betula pendula silver birch	Betul.	•	•	S	slip	mod.	1,3
Castanea sativa sweet chestnut	Fagac.	•		S		one	1,3
Cupressus macrocarpa monterey cypress	Cupress.	•	•	S, E, Summ.	loess	common	1,2,3
Eucalyptus globulus blue gum	Myrt.	•	•	S	loess	few	1,2,3
Fraxinus excelsior european ash	Oleac.	•	•	S	under trees	mod.	1,3
Ilex aquifolium holly	Aquif.	•	•	S		one	2,3
Juglans regia walnut	Jugland.	•	•	S	under trees	few	1.3
Laburnum anagyroides golden rain	Papil.	• X		Summ., (E)		one	1.3

	Family	P	N	Location*	Specific Habitat**	Abundance	Record
Malus x *domestica* apple	Ros.		•	Summ., (E)		few	3
Olearia traversii chathams o.[3]	Aster.	•		SE		few	1,2,3
Picea sp. spruce	Pin.	•		S		two	3
Pinus nigra corsican pine	"	•		S, Summ. (E)		common	1,2,3
P. pinaster maritime pine	"	•		S,E		mod.	1,3
P. radiata monterey pine	"	•	•	S, W, N, E	loess	common	1,2,3
Pittosporum colensoi westland p.[3]	Pitto.	• L					1
P. crassifolium karo[3]	"	•	•	S, NE	talus	one	1,2,3
P. ralphii ralph's p.[3]	"	•	•	SE	under shrubs	one	1,2,3
Populus alba silver poplar	Salic.	•	(•)	S	loess	mod.	1,3
P. nigra lombardy poplar	"	• X		S			1
Prunus armeniaca apricot	Ros.		• X	Summ. (E)		one	3
P. avium cherry	"	•	(•)X	S	under trees	few	1,3
P. cerasifera plum	"		• X	S	grassland	rare	3
P. mahaleb St Lucie cherry	"	• X		S			1
P. persica nectarine	"		• X	Summ. (E)		one	3
Pseudotsuga menziesii douglas fr	Pin.	• ?		S			1
Pyrus communis pear	Ros.	•		S		one	1,3
Quercus ilex holm oak	Fagac.	•	•	S	under trees	mod.	1,2,3
Q. robur european oak	"	•	•	S	under trees	common	1,2,3
Salix cinerea grey willow	Salic.	•	(•)X	S	slip	few, local	3
S. fragilis crack willow	"	• X		S		one	3
Sequoia sempervirens redwood	Taxod.	•		S			1,3
Shrubs							
Berberis glaucocarpa barberry	Berber.	• X		SE		one	3
B. vulgaris barberry	"	• ?		S			1
Buddleja davidii butterfly plant	Buddl.	• X		SE		one	3
Chrysanthemoides monilifera boneseed	Aster.	•	•	NE, NW, S	cliffs, scree, short grassland	common	2,3
Citrus sp.	Rut.	• X		Summ.		one	1
Coprosma repens taupata	Rub.	•		S	cliff top	one	3
Crataegus monogyna hawthorn	Ros.	•	•	Summ., S	grassland, scrub	mod.	1,2,3
Cytisus scoparius broom	Papil.	•	•	S	grassland, scrub	common	1,2,3
Erica sp. heath	Eric.	• X		S			2
Ficus carica fig	Morac.	•		Summ. (E)		one	3
Ligustrum vulgare privet	Oleac.	• X		SE		two	3
Lupinus arboreus yellow lupin	Papil.		• X	SE	sewage treatment area	few	3
Lycium ferocissimum boxthorn	Solan.	•	•	NW, NE	cliffs, scree, short grassland	common	1,2,3
Myoporum insulare tasmanian ngaio	Myop.	• X		E	loess	one	3
Ribes sanguineum red flowering currant	Grossul.	•	•	S, W	scrub, under trees	common	1,2,3
R. uva-crispa gooseberry	"	•	•	S, W	scrub	few	1,2,3
Rosa rubiginosa sweet brier	Ros.	•	•	S, Summ.	grassland, scrub under trees	mod.	1,2,3
Sambucus nigra elderberry	Caprif.	•	•	S	scrub, bracken, under trees	mod.	1,2,3
Syringa sp. lilac	Oleac.	•		S		one	1,3
Ulex europaeus gorse	Papil.	•	•	S, W, NW	scrub, grassland	mod.	1,2,3
Vines							
Clematis vitalba old man's beard	Ranunc.		•X(R)	Summ. (E)	under trees	three	3
Rosa sp. old climbing rose	Rosac.	•		Summ. (E)		two	1,3
Solanum dulcamara bittersweet	Solan.	•	•X	S	under trees	few	3
Herbs							
Grasses							
Agrostis capillaris browntop	Poa.	•	•	widespread	grassland	common	2,3
A. stolonifera creeping bent	"		•	S, W	damp grassland	common	2,3
Aira caryophyllea hair grass	"		•	Summ.	rock outcrop	mod.	2,3
A. praecox hairgrass	"		•	Summ.	short grassland,rock outcrop	mod.	3
Alopecurus geniculatus marsh foxtail	"		•	stock dam	pond	few	3
A. pratensis meadow f.	"		•	Summ. (E)	grassland	few	3

	Family	P	N	Location*	Specific Habitat**	Abundance	Record
Anthoxanthum odoratum sweet vernal	Poa.	•	•	widespread	grassland	common	2,3
Arrhenatherum elatius tall oat grass	"	•	•	S., Summ.	grassland	common	3
Avena fatua wild oat	"		•	NE, W	scree, cliff ledges	mod.	2,3
Briza minor small quaking grass	"		•	Summ.	short grassland	few	3
Bromus diandrus ripgut brome	"		•	widespread	dry grassland, under trees	common	2,3
B. hordeaceus soft brome	"		•	Summ.	dry grassland, under trees	mod.	2,3
B. sterilis barren brome	"		•	widespread	dry grassland, under trees	common	3
B. tectorum barren brome	"		•	widespread	dry grassland	common	2,3
B. willdenowii prairy grass	"	•	•	Summ.	grassland	mod.	2,3
Cynosurus cristatus crested dogstail	"	•	•	S, Summ.	grassland	common	2,3
C. echinatus rough dogstail	"		•	Summ.	grassland	mod.	2,3
Dactylis glomerata cocksfoot	"	•	•	widespread	grassland	common	2,3
Elymus rectisetus wheatgrass	"		•	widespread	grassland	common	2,3
Elytrigia repens old man twitch	"		•	Summ., S	grassland	mod.	3
Festuca arundinacea tall fescue	"		•	S	shoreline grassland	few	3
F. rubra red fescue	"	•	•	widespread	grassland	common	2,3
F. arundinacea x *Lolium perenne* hybrid	"		•	NE	seepage	rare	3
Glyceria fluitans floating sweetgrass	"		•	stock dam	pond	mod.	2,3
Holcus lanatus yorkshire fog	"	•	•	widespread	grassland	common	2,3
Hordeum marinum sea barley grass	"		•	S	salt marsh	few	3
H. murinum barley grass	"		•	Summ., W	dry grassland	mod.	2,3
H. sativum barley	"	•	•	NE	scree	rare	3
Lagurus ovatus harestail grass	"		•	S	dry bank	few	3
Lolium perenne perennial ryegrass	"	•	•	S, W, Summ.	grassland	common	2,3
Parapholis incurva sickle grass	"		•	S,W,NE	salt marsh, loess banks	mod.	3
Phalaris aquatica big canary grass	"		•	Summ., W, S	grassland	common	3
Phleum pratense timothy	"	•	•	S, Summ.	grassland	mod.	3
Poa annua annual poa	"		•	S, Summ.	short grassland	common	3
P. pratensis meadow poa	"	•	•	S, Summ.	grassland	common	2,3
Rytidosperma racemosum "danthonia"	"		•	Summ. (E)	under trees	mod.	3
Stipa sp.	"		•	Summ. (E)	rock outcrop	few	3
Vulpia bromoides squirrel tail	"		•	S, Summ.	short grassland	few	2,3
Other monocotyledons							
Agave americana century plant	Agav.	•		Summ. (E)		one	3
Carex muricata spiny-head c.	Cyper.		•	Summ.	grassland	few	3
Freesia refracta	Irid.	•		leper's grave	garden	few	3
Iris foetidissima stinking iris	"	• X		Summ. (E)	under trees	rare	3
Juncus bufonius toad rush	Junc.		•(R)	S	damp ground	few	3
J. effusus soft rush	"		•	Summ.	swale	few	3
J. filicaulis fine rush	"		•	Summ.	swale	mod.	2,3
Narcissus pseudonarcissus forms (at least 6) daffodil	Amaryll.	•		S, SE, Summ. (E)		mod.	3
N. tazetta forms (at least 3) jonquil	"	•		SE		mod.	3
Scilla hispanica x *non-scripta* bluebell hybrid	"	•		S		few	3
Dicotyledons							
Achillea millefolium yarrow	Aster.		•	Summ. (E,W)	short grassland	few	3
Aeonium arboreum shrubby a.	Crassul.	•	•	NE, N	cliffs	common	2,3
Anagallis arvensis scarlet pimpernel	Primul.		•	S,NE	shelly gravel, scree	common	2,3
Anthriscus caucalis beaked parsley	Apiac.		•	S, Summ.	under trees, short grassland	mod.	2,3
Aphanes arvensis parsley piert	Ros.		•	Summ.	rock outcrop	few	3
Aptenia cordifolia flat-leaved succulent	Aizo.		•	widespread	under trees, on rocks	mod.	2,3
Arctotheca calendula cape weed	Aster.		• L	Summ.	short grassland		2,3
Arenaria serpyllifolia sandwort	Caryoph.		•(R)	S	shelly sand	few	3
Argyranthemum frutescens marguerite	Aster.		•X(R)	S	strand	one	3
Atriplex patula small orache	Chenop.		•X(R)	stock dam, Summ.(E)	pond margin, bare ground	three	3
A. prostrata orache	"		•	S, NE	under trees	mod.	3
Bellis perennis common daisy	Aster.		•	Summ.(E)	short grassland	mod.	2,3
Beta vulgaris wild beet	Chenop.		•	S,W	strand	few	3

	Family	P	N	Location*	Specific Habitat**	Abundance	Record
Brassica cf. *napus* wild rape	Brassic.	•	•	NE	grassy slope	few	3
Calandrinia menziesii curnow's curse	Portulac.		•(R)	NW	bare soil, rock	few	3
Calendula officinalis marigold	Aster.		•X(R)	S	strand	one	3
Callitriche stagnalis starwort	Callitr.	•		stock dam	pond	few	2,3
Capsella bursa-pastoris shepherd's purse	Brassic.		•	S, Summ.	disturbed soil	mod.	2,3
Cardamine hirsuta hairy bitter cress	"		•	S, Summ.	disturbed soil, rock outcrop	mod.	2,3
Carduus tenuiflorus winged thistle	Aster.		•	widespread	dry grassland	common	2,3
Centaurium erythraea centaury	Gent.		•	S	cliff ledges, short grassland	few	3
C. tenuiflorum small centaury	"		•	W	short grassland	few	3
Centranthus ruber red valerian	Valerian.	•	•	W, NE	cliffs, rock outcrop	mod.	2,3
Cerastium glomeratum mouse-ear chickweed	Caryoph.		•	widespread	rock outcrop, short grassland	mod.	2,3
C. fontanum ssp. *vulgare* mouse-ear chickweed	"		•	widespread	short grassland	mod	2,3
Chenopodium album fathen	Chenop.		•	NW, Summ. (E)	shore, on track	few	3
C. murale nettle-leaved f.	"		•	Summ., S	bare ground	mod.	3
C. pumilio clammy goosefoot	"		•	Summ.	rock outcrop	few	3
Cirsium arvense california thistle	Aster.		•	widespread	grassland	common	2,3
C. vulgare scots thistle	"		•	widespread	grassland	mod.	2,3
Conium maculatum hemlock	Apiac.		• X	SE	grassland	mod.	3
Conyza albida fleabane	Aster.		• X	NE	scrub	few	3
C. bilbaoana fleabane	"		•X(R)	SW	under trees	two	3
Crepis capillaris hawksbeard	"		•	widespread	grassland	common	2,3
Digitalis purpurea foxglove	Scroph.	•	•	S	grassland	few	3
Drosanthemum floribundum small ice plant	Aizo.		•X(R)	NE	bare soil, rock	one	3
Erodium cicutarium storksbill	Geran.		•	S, Summ.	short grassland	mod.	2,3
E. moschatum musky storksbill	"		•	S, Summ.	short grassland	few	3
Euphorbia peplus milkweed spurge	Euphorb.		•	Summ. (E)	disturbed soil	mod.	3
Fumaria muralis mauve fumitory	Fumar.		• L	NE			2
Galium aparine cleavers	Rub.		•	S, W, Summ.	scrub	mod.	2,3
Geranium molle dove's foot	Geran.		•	S, Summ.	rocks, short grassland	mod.	2,3
G. pusillum small-flowered g.	"		•	Summ.	rock outcrop	few	3
Hieracium pilosella mouse ear hawkweed	Aster.		•X(R)	S	cliff ledge	rare	3
Hirschfeldia incana hoary mustard	Brassic.		•X(R)	S	shelly gravel	rare	3
Hypochoeris radicata cats ear	Aster.		•	S, Summ.	grassland	common	2,3
Lactuca serriola prickly lettuce	"		•(R)	Summ. (E)	grassland	few	3
Lamium amplexicaule henbit	Lamiac.		•	Summ. (E)	disturbed soil	few	3
Lathyrus latifolius everlasting pea	Papil.	•	•	S	grass under trees	few	3
L. nissolia grass vetchling	"	•	•	S	grassland	mod.	3
L. pratensis meadow pea	"		•	S	damp grassland	mod., local	3
Leontodon taraxacoides hawkbit	Aster.		•	Summ. (E)	rock outcrop	few	3
Lepidium desvauxii narrow-leaved cress	Brassic.		•	S, W, Summ.	under trees, short grassland	mod.	2,3
Linaria purpurea purple linaria	Scroph.		• X	S	bare soil	few	3
Linum catharticum purging flax	Lin.		•	S	short grassland	few	3
Lotus pedunculatus lotus	Papil.	•	•	Summ., S	loess	mod.	3
Malva neglecta small mallow	Malv.		•	Summ.	disturbed soil	few	3
M. parviflora small-flowered m.	"		•	NE	grassy slope	few	3
M. sylvestris large-flowered m.	"		•	S	bank, short grassland	few	3
Marrubium vulgare horehound	Lamiac.		•	S, W, NW	short grassland	mod.	3
Medicago arabica spotted bur medick	Papil.		•	S	short grassland	mod.	3
M. polymorpha bur medick	"		•	S, NE	rock, scree	mod.	2,3
Melilotus indica indian melilot	"		•	S, Summ.	grassland	mod.	3
Melissa officinalis lemon balm	Lamiac.	•	•	Summ.	under trees	few	3
Mimulus guttatus monkey musk	Scroph.		• L	NE		rare	2
Montia fontana ssp. *chondrosperma* water blinks	Portulac.		•	Summ.	bare soil	few	2,3
M. perfoliata miner's lettuce	"		•	S,Summ.	under trees	common	2,3
Nasturtium officinale watercress	Brassic.	•	•	NE	seepage	rare	2,3
Opuntia cylindrica cactus	Cact.	•	• L	NE		rare	2,3
Osteospermum fruticosum dimorphotheca	Aster.		•X(R)	S	shelly gravel	one	3
Petrorhagia prolifera grassy pink	Caryoph.		•(R)	S	beach	few, local	3
Picris echioides ox tongue	Aster.		•X(R)	S	shelly gravel, grassland	few	3
Plantago coronopus buckshorn plantain	Plantag.		•	S	salt marsh	mod.	2,3

	Family	P	N	Location*	Specific Habitat**	Abundance	Record
P. lanceolata narrow-leaved p.	Plantag.		•	S, Summ.	short grassland	mod.	2,3
Polycarpon tetraphyllum all seed	Caryoph.		•	S, Summ.	rock outcrop	mod.	2,3
Polygonum arenastrum wireweed	Polyg.		•	Summ. (E)	on track	few	3
P. aviculare wireweed	"		•	Summ. (E)	on track	mod.	3
Prunella vulgaris selfheal	Lamiac.		•	Summ. (E)	beside track	few	3
Ranunculus acris giant buttercup	Ranunc.		•	S	grassland	mod.	3
R. parviflorus small-flowered b.	"		•	S	grassland.	mod.	3
R. repens creeping b.	"		•	S	damp grassland	mod.	2,3
R. sardous hairy b.	"		•	S	damp grassland	mod.	3
R. sceleratus celery b.	"		•	stock dam	pond	mod.	3
Reseda alba mignonette	Resed.	•	•	S	beach	few	2,3
R. luteola yellow m.	"		•	NE	loess, cliffs	mod.	2,3
Rumex acetosella sheep sorrel	Polyg.		•	S, Summ.	short grassland, rock outcrop	mod.	3
R. crispus curly dock	"		•	S, Summ.	grassland	common	3
R. obtusifolius broad-leaved d.	"		•(R)	S	beach	few	3
Sagina procumbens pearlwort	Caryoph.		•	S, Summ.	disturbed soil	few	2,3
Sanguisorba minor salad burnett	Ros.		•	NE	grassy slope	few	3
Sedum acre stonecrop	Crassul.		•	Summ.	rock outcrop	mod.	2,3
Silene gallica catchfly	Caryoph.		•	S, NE, Summ.	short grassland, rock outcrop	mod.	2,3
Silybum marianum variegated thistle	Aster.		•	widespread	short grassland	common	2,3
Sisymbrium officinale hedge mustard	Brassic.		•	S, Summ.	near trees	mod.	2,3
Solanum nigrum black nightshade	Solan.		•	SE, Summ.	disturbed soil	few	3
S. physalifolium	"		•X(R)	W	shore	rare	3
Sonchus asper prickly sow thistle	Aster.		•	S, Summ.	disturbed soil	few	3
S. oleraceus sow thistle	"		•	S,W	near trees	mod.	2,3
Stachys arvensis staggerweed	Lamiac.		•	Summ.(E)	under trees	few	3
Stellaria media chickweed	Caryoph.		•	S, Summ.	disturbed soil	mod.	2,3
Stuartina muelleri spoon-leaved cudweed	Aster.		•	W	dry grassland	mod.	2,3
Taraxacum officinale dandelion	"		•	widespread	grassland	mod.	2,3
Tragopogon porrifolius salsify	"	•	•	Summ.	grassland	few	3
Trifolium campestre hop trefoil	Papil.		•	S, Summ.	grassland	mod.	3
T. dubium suckling clover	"		•	S, W, Summ.	short grassland	mod.	2,3
T. fragiferum strawberry clover	"		•	S, Summ.	short grassland	mod.	3
T. glomeratum clustered clover	"		•	S	grassland	few	3
T. pratense red clover	"	•	•	S, Summ.	grassland	mod.	2,3
T. repens white clover	"	•	•	S,W, Summ.	grassland	common	2,3
T. striatum striated clover	"		•	S	grassland	mod.	3
T. subterraneum subterranean clover	"	•	•	S	short grassland	mod.	2,3
T. tomentosum woolly clover	"		•	S,W, Summ.	grassland	mod.	2,3
Tripleurospermum inodorum scentless mayweed	Aster.		• X	S, Summ.	bare ground	few	3
Urtica urens nettle	Urtic.		•	S, NW, Summ.	under trees, scrub	mod.	2,3
Verbascum thapsus woolly mullein	Scroph.		•	S, W, Summ.	shelly beach, short grassland	few	2,3
V. virgatum moth mullein	"		•	S	shelly beach, short grassland	few	2,3
Veronica arvensis speedwell	"		•	S, Summ.	disturbed soil, rock outcrop	mod.	2,3
Vicia hirsuta hairy vetch	Papil.		•	widespread	grassland, scrub	common	2,3
V. sativa common vetch	"		•	widespread	grassland	common	2,3
V. tetrasperma smooth tare	"		•	S	grassland	mod.	3
Vittadinia gracilis purple fuzzweed	Aster.		•	S, W	short grassland, under trees	mod.	2,3
Ferns							
Dryopteris filix-mas male fern	Dryopt.		•X(R)	NE, Summ. (E)	loess, hollow, near buildings	few	3
Polypodium vulgare common polypody	Polypod.		•(R)	SE	under trees	few	3

cally sourced, obtained from the Department of Conservation Nursery at Motukarara or in a few cases, from the collection of C.J.B., and nurseries at Lincoln University, Waiora Trust, and Southern Woods, Templeton. The newly planted areas are mapped in Genet & Burrows (1999)

Introduced Plants

Species foreign to the New Zealand flora and deliberately planted on Otamahua are listed in

Table 2 Indigenous species recently planted on Otamahua/Quail Island. key: T, tree; S, shrub; V, vine; H, herb. Species that were not present on Otamahua between 1976 and 1998 are marked •.

Taxon	Numbers Planted		Taxon	Numbers Planted	
	1998	1999		1998	1999
Alectryon excelsum titoki T•		10	*Melicytus ramiflorus* mahoe T		55
Aristotelia serrata wineberry T	23	14	*Myoporum laetum* ngaio T	56	585
Clematis foetida lemon c. V •		5	*Myrsine australis* mapou T		44
Coprosma crassifolia thick-leaved c. S	6	18	*Myrtus obcordata* rohutu S•	2	32
C. lucida shining c. S •		192	*Parsonsia heterophylla* akakiore V •		1
C. propinqua miki miki S		35	*Passiflora tetrandra* passion vine V •		2
C. rhamnoides variable-leaved c. S	3	13	*Pennantia corymbosa* kaikomako T •		4
C. robusta karamu S	256	490	*Phormium cookianum* whararíki H		50
C. rotundifolia round-leaved c. S	3	8	*P. tenax* harakeke H	25	100
C. virescens green-seed c. S	8	38	*Plagianthus divaricatus* salt marsh ribbonwood S		10
Cordyline australis ti-kouka T	64	430	*P. regius* manatu T	50	21
Corynocarpus laevigatus karaka T	2	5	*Podocarpus totara* totara T	16	15
Dacrycarpus dacrydioides kahikatea T •		2	*Pittosporum eugenioides* lemonwood T	121	425
Dodonaea viscosa akeake T •	62	603	*P. tenuifolium* kohuhu T	149	845
Fuchsia excorticata kotukutuku T •		4	*Prumnopitys taxifolia* matai T •	5	3
Griselinia littoralis broadleaf T	58	230	*Pseudopanax arboreus* five-finger T	19	160
Hebe salicifolia koromiko S		40	*P. crassifolius* lancewood T •	8	45
H. strictissima Banks Pen. h. S		124	*Ripogonum scandens* supplejack V •		2
Hedycarya arborea pigeonwood T •		4	*Schefflera digitata* pate T •		3
Hoheria angustifolia houhi T	49	-	*Sophora microphylla* kowhai T	77	450
Kunzea ericoides kanuka T	249	1575	*S. prostrata* dwarf kowhai S		2
Macropiper excelsum kawakawa S	5	36	*Streblus heterophyllus* turepo T •		2
			Total	**1316**	**6697**

Table 1, Part B. It is assumed that almost all non-indigenous woody plants on the island were originally deliberately planted. There are few clear records of when and by whom they were planted.

Limiting dates for some taxa can be gauged from dated photographs, the 1907 survey map, and records of particular kinds of occupations or activities on the island (cf. Jackson 1990). However, the most useful data for these purposes are those in the earliest published plant lists (Sissons 1976; Chapman 1978; Molloy 1979). Sissons' list, only for woody taxa, includes some native species and almost all of the planted introduced species which are still present on the island (Table 1). Sissons noted that planting of foreign trees for shelter and amenity was nearly all carried out between 1874 and 1900. He indicated species composition in several locations on the SE side of the island. He also noted that many old conifers were wind-thrown and provided a generalized map of the vegetation which shows extensive wind-break plantations on the summit plateau, that have subsequently been removed.

It appears that other individual species were also removed after 1976 (Table 1, and Ian Hill, pers. comm). The *Pseudotsuga* record by Sissons (1976) may have been an error; two old trees of *Picea* sp. (which Sissons did not record) at the Leper Hospital site (Fig. 1) were probably mistaken for it. *Berberis vulgare* and *Solanum aviculare* are also likely to have been mistaken identifications, for *B. glaucocarpa* and *S. laciniatum,* respectively. Some of the absences are due to deliberate removal of plants, during activities to clear potential weedy species such as *Acer pseudoplatanus,* and *Prunus mahaleb,* but it is not known why other orchard or amenity species *(Citrus* sp., *Populus nigra, Prunus armeniaca, P. persica)* were removed.

The 1979 list of Otamahua plants resulted from two days of fieldwork in 1978 (Molloy 1979). As well as the woody species, many herbaceous species, both indigenous and introduced, were recorded by Molloy and he separated the taxa into natural (i.e. truly indigenous) and planted or adventive categories. Molloy (1979) added several more woody species to the overall list of taxa on the island: *Ilex aquifolium,* "rare, S.W. coast"; *Erica* sp. "rare, S. coast"; *Berberis glaucocarpa* "occasional throughout"; *Chrysanthemoides* (as *Osteospermum) monilifera,* "occasional N.E." The *Erica* and *Berberis* were later removed (as well as the species already noted). The removal of woody species with the propensity to be weedy, and some herbaceous species, has continued to the present day (cf. Burrows in press).

A few of the introduced herbaceous taxa on Molloy's list have not been seen during the 1997-99 fieldwork. They are: cape weed, *Arctotheca calendula*;* mauve fumitory, *Fumaria muralis;* monkey musk, *Mimulus guttatus;* and cactus *Opuntia cylindrica**. H.D.W. noted the presence of the two marked * during his field work in the mid 1980s.

A few other woody introduced species were added to the overall list (Table 1) during the most recent fieldwork *(Malus* x *domestica*[1], *Prunus cerasifera*[1], *Lupinus arboreus*[2], *Salix cinerea*[2], *S. fragilis*[2], *Buddleja davidii*[3], *Coprosma repens*[3], *Ficus carica*[3], *Ligustrum vulgare*[3], *Clematis vitalba*[4]). These were respectively: 1, planted accidentally or deliberately since 1990; 2, planted accidentally or deliberately since 1980; 3, established during the farming period prior to 1980; 4, introduced naturally in about the last decade. Also, 94 introduced herbs and 2 ferns have been added to the overall flora of Otamahua during recent fieldwork (Wilson 1986-88, Meurk 1997, Burrows 1997-99). As will be noted later (and cf. Burrows in press) there appears to be continuing accretion of such plants to the island in various ways.

Considering all non-indigenous herbaceous species on the island it is evident that some were originally deliberately brought there as seeds, or plants. Among them were grasses and clovers, sown for pasture, and various garden specimens. However, it is very unlikely that many of the foreign herbaceous plants reached the island as a result of deliberate introduction. Some taxa will have arrived on their own, by various means of oversea transport. Most introduced plants almost certainly arrived accidentally, by means connected with human activities on the island (as contaminants in pasture seed mixtures; on human clothing or footgear; on the coats or in the guts of farm stock; on farm machinery; in hay or straw or various kinds of packing material; in soil brought in with other plants).

Many of the planted introduced woody or herbaceous taxa, including species originally put in for shelter or in gardens for amenity or for pasture, have "escaped" by regenerating in various ways and spreading. These, and the foreign species which arrived by natural means or accidental human introductions, have become well and truly naturalised. Many occur widely on the island, some in great abundance (Table 1). Other introduced taxa, as noted in the table, show no sign of spreading whatsoever.

Some specific cases

Edward Ward (Ward 1851) recorded the planting of various foreign species on Otamahua:

p. 178 Apple pips *(Malus* x *domestica)* and a peach stone *(Prunus persica)* in three different places (originally from "Hobart town or Launceston", Tasmania); p. 179 larch seeds (probably *Larix decidua).* If any of these gave rise to plants, none have persisted. *Malus* x *domestica* and *P. persica* (nectarine) once grew near the Visitor Centre at the east end of the island, but were planted there as part of an orchard in the Quarantine Station era, and were removed in the early 1980s (Ian Hill pers. comm.)

p. 182 Seeds of bluebell* *(Scilla hispanica* x *non-scripta),* foxglove* *(Digitalis purpurea),* broom*

(Cytisus scoparius), vetchlings* *(Lathyrus nissolia)* and poppy (possibly *Papaver rhoeas)* (brought from Killinchy, in Ireland); p. 185 cabbage plants *(Brassica oleracea)* and fruit trees;

p. 186 Slips (cuttings) of gooseberries* *(Ribes uva-crispa)* and currants (probably blackcurrant, *Ribes nigrum,* or redcurrant *R. rubrum).*

p. 192 "Whins" (gorse*) *(Ulex europaeus).* Those marked * occur on the island now and some populations at least are likely to be derived from these original plantings.

On the island the main stands of large monterey pine *(Pinus radiata),* corsican pine (*P. nigra),* maritime pine (*P. pinaster),* monterey cypress *(Cupressus macrocarpa)* and one large area of european oaks *(Quercus robur)* were planted between about 1874 and 1900 (cf. the 1907 survey map, p. 57, Jackson 1990). Most of the other woodland plantings, which include a variety of introduced trees and shrubs, were done between 1907 and about 1980 (see Table 1). The development of woodland was associated with uses of the island for farming (intermittently from 1852- 1985), and a human and animal quarantine station (about 1875- 1931). Trees were planted for shelter, amenity, firewood and erosion control. Gardens were also established and a few relics persist, especially near the visitor information centre, e.g. an old rose *(Rosa* cf. *wichuraiana),* a fig *(Ficus carica),* a century plant *(Agave americana)* and many clumps of daffodils *(Narcissus* spp.), evident in spring. Daffodils, freesias and bluebells grow near the leper's grave and a lilac *(Syringa* sp.*),* everlasting pea *(Lathyrus latifolius)* and rose *(Rosa* sp.*)* near the Leper Hospital site (Fig. 1).

The shrubs hawthorn *(Crataegus monogyna),* boxthorn *(Lycium ferocissimum),* elderberry *(Sambucus nigra),* red-flowering currant *(Ribes sanguineum)* and boneseed *(Chrysanthemoides monilifera)* were almost certainly introduced for hedges (as gorse and broom had been), or planted near buildings as attractive amenity species. They have escaped and occur widely on the island. Boneseed and currant are the most abundant. Efforts have been made by Department of Conservation staff in recent years to reduce the populations of all of these shrub species because of their potential for increase and spread (Murray Lane, John Trotter, John Watson, pers. comm.). The Otamahua/Quail Island Ecological Restoration Trust has begun a long-term programme of eradication of them (cf. Burrows in press).

Between 1870 and 1900 the summit plateau of the island was divided into paddocks with wire fences (Jackson 1990). The main pasture development, which involved cultivation of the large paddocks and the sowing of seeds of high quality grasses such as cocksfoot *(Dactylis glomerata),* timothy *(Phleum pratense)* and ryegrass *(Lolium perenne)* apparently took place over this period. Fodder, grain and root crops appear to have been grown then and later, also.

Contemporary photographs taken from 1906-1930 show more silver tussock on the unworked southern slopes than is now the case; this may partly relate to regular sheep-grazing at that time compared with no grazing since 1985 (Jackson 1990). After stock grazing ceased, tall, dense swards of the introduced grasses very largely replaced the tussock except on the driest sites. The pasture grasses and various dicotyledon herbs, such as white clover *(Trifolium repens),* have spread very widely over the island. Stock will have been responsible for transfers of some seeds but some may have been broadcast sown. Nevertheless the species composition on what were once worked paddocks and locations which have never been cultivated is somewhat different. Fertilizer applications and concentrated returns of dung and urine on the cultivated paddocks probably have contributed to these differences.

The suggested origins (accidental introductions and natural immigration across the surrounding sea) for many of the herbaceous introduced plants on Otamahua are deduced from knowledge of the behaviour of these species elsewhere in Canterbury and New Zealand. Most are common weeds of farms, gardens, lawns and

Table 2 Adventive species which appear to have migrated recently to Otamahua.

Taxon	Location; habitat	Dispersal mode (possible origin on island)	Potential for spread on island	Action taken
A. Represented by one individual or very few				
Arenaria serpyllifolia sandwort	Walkers Beach; fine shell grit	? flotation	limited	
Atriplex sp. cf. *patula* small orache	stock water dam; dried muddy bottom	?ducks	probably limited	removed 1998
Calandrinia menziesii curnow's curse	northernmost tip of island; exposed soil, rocks in bird colony	? seabirds	probably moderate	
Calendula officinale marigold	Ski-lane Beach; in drift-line on shore	? flotation	probably moderate	removed 1998
Clematis vitalba old man's beard	near old farm buildings; under pine trees	wind (plumed achene)	probably moderate	removed 1998
Conyza albida fleabane	above Ward's Beach, near visitor centre	wind (plumed achene)	unlimited	removed 1998
C. sp. cf. *bilbaoana* fleabane	near Ship's Graveyard; under trees	wind (plumed achene)	unlimited	removed 1998
Drosanthemum floribundum small ice plant	north-eastern tip of island; exposed soil, rock, near bird colony	? birds	probably moderate	removed 1998
Dryopteris filix-mas male fern	above north-eastern cliffs; hollow in loess; near visitor centre	wind (tiny spore)	probably unlimited	removed 1999
Hieracium pilosella mouse-ear hawkweed	east end Walker's Beach; ledge on rhyolite cliff	wind (plumed achene)	probably moderate	removed 1998
Hirschfeldia incana hoary mustard	Walkers Beach; fine shell grit	? flotation	limited	removed 1998
Juncus bufonius toad rush	near old farm buildings; damp hollows	? on visitor footgear	limited	
Lactuca serriola prickly lettuce	near old farm buildings; disturbed ground	? on visitor clothing	probably moderate	
Linaria purpurea purple linaria	near visitor information centre; bare soil	? on visitor footgear	probably unlimited	removed 1998
Osteospermum fruticosum dimorphotheca	Walkers Beach; fine shell grit	? flotation	probably moderate	removed 1998
Polypodium vulgare common polypody fern	track up from jetty; under conifer trees	wind (tiny spores)	moderate	
Prunus cerasifera cherry plum	Swimmer's Beach and track up from jetty; grassland	human discard	unlimited	removed 1998
Rumex obtusifolius broad-leaved dock	Walkers Beach; fine shell grit	? flotation	probably moderate	removed 1999
Solanum physalifolium hairy nightshade	above beach, N.W. slopes	? flotation	moderate	removed 1999
Tripleurospermum inodorum scentless mayweed	near visitor information centre; bare soil	? on visitor footgear	probably moderate	removed 1998
B. Represented by tens to hundreds of individuals				
Petrorhagia prolifera grassy pink	Walkers Beach; fine shell grit	? flotation	limited	
Picris echioides ox-tongue	Walkers Beach; fine shell grit and grassland	? wind, flotation	probably moderate	removed 1998
Ranunculus sceleratus celery-leaved buttercup	stock water dam; dried muddy bottom	? ducks	limited	attempted removal 1999
Verbascum virgatum moth mullein	Walkers Beach and adjacent shore; fine shell grit, disturbed ground	? flotation	probably moderate	attempted removal 1999

waste ground in our region. A few are grown as garden specimens. Most were on the island by 1978 (Molloy 1979). There are no records of how the majority of these species arrived on the island; likely ways in which accidental introductions happened were outlined earlier. Some recent finds, to be noted later, are edifying, in relation to probable natural immigration.

Phalaris aquatica, big canary grass, is an easily recognized species, not recorded by Molloy (1979). On the island it is confined almost entirely to the area around the farm buildings and visitor information centre on the summit plateau at the eastern end of the island, as well as near the stock water dam at the western end of the island and along some of the tracks. It is surmised that this species was introduced, probably on earth-moving machinery used to do various tasks in these localities, in the early 1980s.

Two other accidental introductions to Otamahua in the same period, yellow lupin, *Lupinus arboreus* and hemlock, *Conium maculatum,* were brought to the island with sand, when a sewage treatment system was established (Claire Findlay, pers. comm.). The adults were recently removed and the sites will be kept under surveillance in case of regrowth from seeds.

Plant taxa listed in Part A of Table 3 were found on Otamahua in 1998- early 1999. The small populations (often one plant only, or small groups) suggest that these have arrived recently. The likely methods of transport to the island are noted. Most of the individuals or groups have been removed; a watching brief will be kept on the locations. Several other species, represented by larger populations (Part B, Table 3) may also have been recent immigrants. They could be eradicated, as desired. Some of them are considered further in the next section.

Birds as potential dispersers of seeds to Otamahua

Some plant species on the island occur only near sea-bird (black-backed gull, *Larus dominicanus)* colonies (curnow's curse, *Calandrinia menziesii;* small ice plant *Drosanthemum floribundum).* Although each has dry, dehiscent capsules it is possible that their seeds have been carried to the island by the birds, by adhering to them externally. Celery-leaved buttercup, *Ranunculus sceleratus* and small orache, *Atriplex* cf. *patula* have recently been recorded from the pond at the stock water dam. Each could have been brought to the locality by ducks (mallard, *Anas platyrhynchos,* or paradise shelduck, *Tadorna variegata).*

Whether or not seeds from woody species which bear fleshy fruit have been brought to the island by birds is a moot point. The birds which might perform this function are bellbirds *(Anthornis melanura);* blackbirds, *(Turdus merula);* silvereyes, *(Zosterops lateralis);* and possibly starlings, *(Sturnus vulgaris).* The evidence from seed-trapping on the Port Hills, western Banks Peninsula is that bellbirds, blackbirds, and silvereyes are the main seed dispersers in our region and do not carry seeds over very long distances (only a few tens or hundreds of metres). Starlings are not known to eat many kinds of fruit in this region and there are no clear indications that they carry seeds very far. Kereru *(Hemiphaga novae-seelandiae)* are also important fruit eaters and transport seeds over distances of at least two kilometres (Burrows 1994a 1994b, 1998). However their numbers are low and they fly to Otamahua very rarely. Bellbirds are also uncommonly seen on the island.

Three pieces of circumstantial evidence are against there being an influx of seeds to the island as a result of bird transport. 1. Although there has been ample time and opportunity, foreign fleshy fruited species which could be expected to have reached the island, if birds were regularly transporting seeds there, have not yet arrived, (e.g. cotoneasters, *Cotoneaster* spp.; ivy, *Hedera helix*; himalaya honeysuckle, *Leycesteria formosa*; vine honeysuckles, *Lonicera* spp.; rowan, *Sorbus aucuparia).* 2. With the exception of a few *Prunus cerasifera* plants that almost certainly grew from plum stones cast away by visitors, no new fleshy-fruited species appear to have arrived on the island since Molloy's (1979) report.

3. One of the most likely candidates for bird carriage to Otamahua, boneseed, should occur commonly on the southern side of the island, if oversea transport of seeds was happening. The closest infestations of the species on the mainland are on the headlands to the south and east, near Charteris and Church Bays (about 0.9 km distant). However, on the island the species is mainly on the north to north-east aspects. Molloy (1979) recorded its presence as "occasional, northeast"; it is now very abundant there. Although in summer its seeds are noticed widely on the island, bird traffic (particularly by blackbirds) carries relatively few seeds of the species beyond this main concentration, beneath the north-eastern cliffs. As with others among the woody fleshy-fruited species boneseed has attractive flowers and is often grown in gardens. Almost certainly the original plant(s) from which the present large population is derived, reached the island in this way.

Vegetation

This brief account of the vegetation on Otamahua is based on recent field observations, and reference to recent colour vertical aerial images (SN 97/03 No. 10, March 1997). No quantitative surveys of the plant cover have been attempted.

The main plant assemblages, distinguished by physiognomy and broad composition and, in some cases by habitat conditions, are those of: grassland; fernland; shrubland; treeland; and open habitats such as cliff and associated colluvium, minor areas of rock outcrop, beaches and the very limited areas of wet ground. Species lists for samples from these kinds of vegetation are given in Appendix 1 and extensive areas of them are marked in Fig. 1.

Grassland

Most of the island (about 60%) is covered by grassland in which introduced species of grasses and forbs predominate. In the formerly worked paddocks native species are scarce. Areas that were not ploughed and developed for pasture (mainly on steeper slopes facing north-west - west south-west - south - south-east, see Fig. 1) are dominated by introduced grasses, but indigenous grass and forb species are present, and sometimes locally prominent. Species composition of the solely introduced, or partly indigenous, grasslands is highly variable according to local site conditions (Appendix 1). Appendix 2 notes soil characteristics for the main kinds of grassland sites.

Fernland

Large patches of bracken fern *(Pteridium esculentum)* occur in a few places on the southern aspects of the island, especially above Walkers Beach and Ski-lane Beach and near the leper's grave. Often the bracken is associated with shrubland; grasses are excluded by the dense fern canopy and rhizome mass.

Shrubland

Indigenous shrub species form scattered clumps or patches, or occur as isolated individuals mainly on west-facing slopes and on the shaded slopes extending east from the Ship's Graveyard to above the planted conifer and oak woodland at Ski-lane and Swimmers Beaches (Fig 1). There are complex mosaics with grassland and bracken fern; introduced shrubs are also scattered throughout and in a few places young pine trees are invading the fern and scrub. Another component in a few places on steep slopes near the shore is harakeke *(Phormium tenax),* a large monocotyledon herb.

Matagouri *(Discaria toumatou) is* the most abundant native shrub, equalled in importance on drier, exposed sites by the hummock-forming vine, *Muehlenbeckia complexa. Coprosma* spp., especially C. *crassifolia,* are also prominent. Kanuka *(Kunzea ericoides)* individuals are common near Walker's Beach and a small patch of this species stands beside the stock water dam. One area of manuka *(Leptospermum scoparium),*

near the southwestern corner of the island, is suffering serious encroachment by *Pinus radiata* (planted adults and wild young trees). Smaller stands occur above Ski-lane Beach. All manuka on Otamahua is infested by manuka blight, to some extent. Poroporo *(Solanum laciniatum) is* widely scattered in scrub and woodland, ongaonga *(Urtica ferox)* occurs in several places and some patches of native broom *(Carmichaelia australis)* are present on southern, western and northeastern slopes.

In a few places (at the west end of the island, above Swimmers Beach, and beneath the northern cliffs) are mixed shrubberies of native and exotic shrubs and vines. Pohuehue plants *(Muehlenbeckia australis,* and *M. complexa)* often overgrow the shrubs. Native and introduced shrubs are also found beneath some of the introduced woodland, especially among oaks and other deciduous species.

Scrub in which introduced species dominate almost exclusively is confined mostly to the steep slopes facing north-east to north. Boneseed is the most abundant species, with boxthorn being mainly confined to the bays near the northernmost tip of the island and adjacent western bays. Red flowering currant is especially prominent in one area under planted oak trees above Swimmer's Beach, but is scattered widely on planted woodland margins and in scrub patches elsewhere.

Gorse and broom have been much reduced in recent years; but vigorous regrowth of young broom plants is still occurring on southern aspects. Gorse is regenerating on southern and northwestern aspects and near the Ward Homestead site (Fig. 1). In 1999 Department of Conservation staff have carried out a control operation, with herbicide, against these weeds (John Trotter, pers. comm.).

Treeland

Isolated indigenous trees descended from parents which originally grew in natural woodland occur in a few places as noted earlier (Table 1). Except for a few individuals planted on the southeastern part of the island (cf. Sissons 1976, Molloy 1979) all other well-grown indigenous trees and many shrubs were planted in the early 1980s and most occur in clumps near the jetty, at the east end of Swimmers Beach and around the farm buildings and visitor information centre (Fig. 1). The species assemblages are indicated in Table 1 and Appendix 1.

The most abundant introduced trees, (mainly on or adjacent to the sites where they were originally planted) are monterey pine, monterey cypress, and european oak. Monterey pine is the species that has spread most extensively. Left alone it would probably expand to occupy much of the island; monterey cypress, also spreads, but less widely. Other trees that are relatively common, and spreading include evergreen holm oak, (*Q. ilex);* european ash *Fraxinus excelsior;* silver poplar *Populus alba;,* corsican pine, *Pinus nigra;* and *Eucalyptus globulus,* bluegum.

Ground vegetation cover is virtually nil beneath the densest planted woodland (some of the monterey cypress stands). It is also limited (sparse to almost nil) in some monterey pine stands but usually some annual grasses and forbs grow in these, as they are more open. Competition by tree roots for scarce water in summer, as well as lack of light, are the limiting factors. Ground cover (mainly grass and some shrubs) is more abundant in the planted deciduous woodlands (Appendix 1).

Cliffs

The basalt and conglomerate cliff faces on the north side of the island are very harsh, hot, dry habitats. Nevertheless some species of plant, particularly the succulent shrubby aeonium *(Aeonium arboreum)* and the native ice plant *(Disphyma australe)* inhabit them. Plant cover is most abundant on ledges, but some plants grow in crevices also. Scattered boneseed and boxthorn also live in these sites.

On the more broken cliffs, mainly on northwest aspects, red valerian, *Centranthus ruber* is

common. Cliffs on southern aspects, are developed on rhyolite. Though the rock is relatively infertile, moisture is less limited. The ledges carry a cover of creeping grasses, forbs and some shrubs.

Rock outcrops

Small basaltic bluffs and surface outcrops on the margins of the summit plateau have a sparse cover of introduced herbs and some native species, including ferns (particularly *Cheilanthes humilis,* rock fern) which inhabits crevices. The tiny, native, winter-green, yellow star *(Hypoxis hookeri)* also occurs in this kind of site, inhabiting soil-filled depressions in the rock outcrop. The small native succulent *Crassula sieberiana* and various adventive herbs, are winter annuals which also die down in summer. Some of the more shaded bluffs have regular water seepage which maintains other ferns, the only localities for them on the island (Table 1).

Beaches

Boulder beaches occur on the north and northwest sides of Otamahua. Only where there is a degree of protection from storm waves is there much plant cover (mixtures of grasses and forbs). Southern and western beaches are more sheltered and tend to be shelly. A minor development of salt marsh, with indigenous (e.g. *Sarcocornia australis)* and introduced (e.g. *Plantago coronopus)* species, occurs in hollows on the shelly gravel and sand at Walkers Beach. Otherwise introduced grasses and forbs occupy the strand. Salt marsh ribbonwood, *Plagianthus divaricatus* is sparsely present.

Wetlands

Only one really wet site, the stock dam, is present and it often dries out in summer. Rushes *(Juncus* spp.) and sedges *(Carex virgata)* grow around its margin. The pond contains various smaller herbs

Table 4 Statistics for the flora of Otamahua up to August 9, 1999. Excludes species planted in 1998 and 1999 (see Table 2).

Indigenous Taxa	Trees	Shrubs	Vines	Monocot. Herbs	Dicot. Herbs	Ferns	Total
Original indigenes and a few recently self-introduced species	7	18 (2)	7	28 (2)	49 (3)	12 (1)	121
Additional planted species, native to Banks Peninsula*	8	3		1			12
Additional planted species not native to Banks Peninsula**	4 (1)	1					5
Total	**19**	**22**	**7**	**29**	**49**	**12**	**138**
	( ) species apparently lost since 1976						
Introduced Taxa							
Species known, or assumed to have been planted***	28 (7)	19 (7)	1	18(1)	22 (1)		88
Species assumed to have been self- introduced or accidentally introduced	1 (1)		2 (1)	28	98 (17)	2 (1)	131
Total	**29**	**19**	**3**	**46**	**120**	**2**	**219**
	( ) species removed, or lost since 1976						
Grand Total							357

* More than half of the planted woody indigenous species are in the process of becoming naturalised

** In Table 1 these are listed among introduced taxa

*** About half of the woody introduced species and almost all of the herbaceous introduced species are now naturalised.

otherwise absent from the island. When the pond was dry 1997-mid 1999, it was overrun by *Phalaris aquatica* and *Ranunculus sceleratus.* On the summit plateau shallow swales are marked by patches of rushes, *Juncus* spp. and some *Carex virgata,* denoting moisture accumulation. The harakeke *(Phormium tenax)* stands on southern aspects also indicate damp sites. A distinctive habitat occurs under some of the northeastern cliffs where water seeps out under overhangs. This is the only location on the island for several native species, e.g. duckweed, *(Lemna minor),* coastal deyeuxia, *(Deyeuxia billardieri),* blue fescue, *(Festuca actae),* coastal club sedge, *(Isolepis cernua),* sea primrose, *(Samolus repens)* and native sow thistle *(Sonchus kirkii).*

Conclusion

At present introduced plants dominate the flora and vegetation of Otamahua. Table 4 summarizes the proportions of indigenous and introduced plants in the flora. As Genet & Burrows (1999) explain, the intent of the ecological restoration project on Otamahua is to replace about half of the introduced grassland cover with woodland composed of native species. As this woodland develops more indigenous species could be established, including various herbs and ferns and vines, shrubs and trees not represented on the island. Although the introduced plant cover (especially grassland) will be diminished it is unlikely that the flora of introduced species will change rapidly, except for the loss of species for which there is a policy of eradication (Burrows in press). Additions of more adventive plants can be expected, however.

Regular monitoring is needed to record gains of plant species to the flora and any losses, especially of the rarer native species. As Burrows (in press) indicates various policy decisions are needed on practices to prevent entry of unwanted foreign plants to the island and means to deal with them if they do arrive.

As Otamahua is isolated from the mainland it is possible that some of its truly indigenous plant taxa are genetically distinct to some degree. Before the restoration plantings proceed much further some investigation of this point should be made, especially for bird-, or insect-pollinated species (e.g. *Leptospermum scoparium, Olearia paniculata, Discaria toumatou, Phormium tenax, Hebe strictissima, Convolvulus verecundus, Linum monogynum).*

On Otamahua, in places not being planted with woodland, there is also a very good opportunity to investigate the interactions between native and introduced plant species (in this case in the absence of vertebrate grazers and browsers). In spite of a long history of plant ecological research in this country fundamental studies on this subject are lacking.

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Appendix 1 Representative samples of vegetation composition on Otamahua. Treeland from 20 × 20 m areas, fernland, shrubland from 10 × 10 m areas, all others from 5 × 5 m areas. Key: *, dominant species; (j) juveniles only.

1. Grasslands

(a) Swale near Stock Dam
N.W. aspect
moist
*Agrostis capillaris**
*Anthoxanthum odoratum**
*Dactylis glomerata**
Cirsium arvense
C. vulgare
Festuca rubra
*Holcus lanatus**
Hypochoeris radicata
Juncus sp.
Poa pratensis
Vicia sativa

(b) Slope near Visitor Centre
S. aspect
moist
*Acaena novae-zelandiae**
*Ag. capillaris**
*An. odoratum**
Arrhenatherum elatius
*Dac. glomerata**
Cir. arvense
Hol. lanatus
Hyp. radicata
Ranunculus sardous
Senecio glomeratus
Taraxacum officinale
Vi. sativa
Wahlenbergia gracilis

(c) Near Implement Shed
level site
moist
Dac. glomerata
Hol. lanatus
*Phalaris aquatica**
Tar. officinale

(d) Slope E of Swimmers Beach
S. aspect
dry
*Ag. capillaris**
*An. odoratum**
Cynosurus cristatum
Elymus rectisetus
*Fes. rubra**
Hyp. radicata
Plantago lanceolata
Poa cita
Trifolium pratense
Vi. sativa

(e) Slope in Middle Gully(N.E. Cliffs)
N. aspect
dry
Ac. novae-zelandiae
Dac. glomerata
Dichelachne crinita
*El. rectisetus**
Fes. rubra
Plan. lanceolata
Po. cita
*Rytidosperma clavata**
Sen. glomeratum
Silene gallica
Vi. sativa
V. tetrasperma

(f) Slope above Ballast Quarry
N.W. aspect
dry
Bromus spp.*
Carduus tenuiflorus
El. rectisetus
*Hordeum murinum**
Hol. lanatus
Lolium perenne
Rumex acetosella

(g) Slope near farm buildings
N.E. aspect
dry
Ag. capillaris
Cynosurus echinatus
Dichondra repens
*El. rectisetus**
Oxalis rubens
*Ryt. clavata**
Sil. gallica
Vicia hirsuta

2. Fernland

(a) Gentle Slope near Leper's Grave
S. aspect
moist
Carmichaelia australis
Coprosma crassifolia
Discaria toumatou
Muehlenbeckia complexa
*Pteridium esculentum**
Ribes sanguineum
Sambucus nigra

(b) Slope above Walkers Beach
S. aspect
moist
Car. australis
Cop. crassifolia
C. propinqua
Dis. toumatou
Muehlenbeckia australis
Mu. complexa
Phormium tenax
*Pter. esculentum**
Sam. nigra

3. Shrubland

(a) Ridge near Quarry
S. aspect
dry
*Cop. crassifolia**
Mu. complexa
Sam. nigra

(b) Gentle slope near Stock Dam
W. aspect
moist
*Cop. crassifolia**
*Cop. propinqua**
C. virescens
Crataegus monogyna
*Mu. australis**
Sam. nigra
Solanum laciniatum
Urtica ferox

(c) Slope above Ski-lane Beach
S. aspect
moist
*Dis. toumatou**
Grat. monogyna
Ulex europaeus
Ac. novae-zelandiae
Ag. capillaris
Dac. glomerata

(d) Slope S. of Walkers Beach
S. aspect
dry
Asplenium flabellatum
*Leptospermum scoparium**
Polystichum richardii
Senecio minimus
Urt. ferox

(e) Slope above Walkers Beach
S. aspect
dry
Car. australis
*Cop. crassifolia**
*Kunzea ericoides**
*Ag. capillaris**
An. odoratum
Dac. glomerata
El. rectisetus
Wahl. gracilis

(f) Slope beneath N.E. cliffs
N. aspect
dry
Chrysanthemoides monilifera

4. Treeland

(a) Near Stables
E. aspect
dry
*Cupressus macrocarpa**
*Pinus nigra**
*P. radiata**
(open stand)
Bromus spp.
El. rectisetus
Medicago polymorpha
Montia perfoliata
Ryt. clavata
Sisymbrium officinale
Stipa sp.

(b) Above New Jetty
S.E. aspect
dry
*Cu. macrocarpa**
*Pi. radiata**
(closed stand with a few openings)
in openings
Cu. macrocarpa (j)
Pol. richardii
Ryt. clavata

(c) Above Swimmers Beach
S. aspect
moist
*Quercus robur**
Ac. novae-zelandiae
Ag. capillaris
Crat. monogyna (j)
Dac. glomerata
Digitalis purpurea
Galium aparine
Mu complexa (j)
Quer. robur (j)
Rib. sanguineum
Rosa rubiginosa (j)
Sam. nigra (j)

(d) Above Ski-lane Beach
S. aspect
moist
*Fraxinus excelsior**
*Juglans regia**
Ac. novae-zelandiae
Ag. capillaris
Cir. arvensis
Cir. vulgare
Dac. glomerata
Frax. excelsior (j)
Hol. lanatus
Jug. regia (j)
Phleum pratense
Ranunculus repens
Rib. sanguineum
Sam. nigra (j)
Vi. sativa

(e) Near New Jetty
S.E. aspect
dry
Cordyline australis
*Myoporum laetum**
Olearia avicenniifolia
*O. paniculata**
*Pi. radiata**
Quercus ilex
Bromus spp.
Cu. macrocarpa (j)
Dac. glomerata
El. rectisetus
Lol. perenne
Ol. paniculata (j)
Pol. richardii
Ryt. clavata
Vulpia bromoides

(f) Swimmers Beach
S. aspect
moist
*Aristotelia serrata**
Cordyline australis
Kun. ericoides
*Myo. laetum**
*Myrsine australis**
*Pittosporum eugenioides**
Car. australis
Coprosma robusta
Haloragis erecta
Ol. avicenniifolia
O. paniculata
Phor. tenax
Dac. glomerata
Myrs. australis (j)

(g) Visitor Centre
level site
moist
Cord. australis
Griselinia littoralis
*Hoheria angustifolia**
Kun. ericoides
*Myo. laetum**
*Pitt. eugenioides**
*Pseudopanax arboreus**
Sophora microphylla
Hebe salicifolia
H. strictissima
Bromus spp.
Coprosma propinqua (j)
Melicytus ramiflorus (j)
Mu. australis (j)
Pitt. eugenioides (j)

5. Wetland

(a) Slope near South Point
moist (seepage)
Car. australis
Cord. australis
Cytisus scoparius
*Phor. tenax**
Pter. esculentum

(b) Stock Dam
level site
moist (pond)
*Carex virgata**
Glyceria fluitans
*Juncus gregiflorus**
*Phal. aquatica**
*Ranunculus sceleratus**

6. Beach

Walkers Beach
level site
moist (hollow)
Cotula coronopifolia
Pholiurus incurvus
Plantago coronopus
Puccinellia stricta
Sarcocornia quinqueflora
Spergularia media

7. Rock Outcrop

Near Middle Track
S.E. Aspect
dry
Aira caryophyllea
An. odoratum
Bromus sp.
Cheilanthes humilis
Crassula sieberiana
Erodium cicutarium
Trifolium fragiferum

8. Cliff

Near N.E. Point
N.E. aspect
dry
Aeonium arboreum
Disphyma australe

9. Talus

Slope near Middle Gully
N.E. aspect
dry
Anagallis arvensis
Avena fatua
Bromus sp.
Einadia triandra
Vi. hirsuta

Appendix 2 Brief profile descriptions for some grassland soils on Otamahua.

Very Dry Sites (lack of moisture limiting).

(a) Above rock outcrop near Visitor Centre. Level site.
25 cm dark brown organic loam, fine-medium crumb structure.
On basaltic rock.
Plant cover *Anthoxanthum odoratum, Elymus rectisetus.*

(b) Above NE cliff. 5° slope.
20 cm black organic loam, fine crumb structure.
On basaltic boulders eroded from conglomerate.
Plant cover *Rytidosperma clavata, Bromus* sp., rare *Poa cita.*

Dry Sites (lack of moisture and fertility limiting).

(c) N of row of *Quercus ilex* on summit plateau. 10° slope.
15 cm greyish-brown silt loam, coarse crumb structure.
Grades into >15 cm yellow-brown silt loam, weak nutty to massive structure.
Plant cover *Bromus* spp.

(d) Open area SW of Visitor Centre. 15° slope.
10 cm grey silt loam, medium crumb structure.
Grades into >20 cm yellow-brown silt loam, weak nutty to massive structure.
Plant cover *Agrostis capillaris, Festuca rubra.*

Moist, But Well-aerated Sites (good nutrient and moisture supply).

(e) Near Cross Track to NE cliffs. 10° slope.
22 cm dark greyish-brown organic silt loam, nutty structure.
Grades into >10 cm yellow-brown silt loam, coarse crumb-nutty structure.
Plant cover *Dactylis glomerata, Bromus wildenowii.*

(f) Below summit of Island, NW side, 10° slope.
28 cm greyish-brown silt loam, medium crumb structure.
>10 cm yellow-brown silt loam, medium crumb structure.
Plant cover *Dactylis glomerata, Acaena novae-zealandiae.*

Wet Sites (gley conditions) (over-supply of moisture, at least periodically, and low nutrient supply limiting).

(g) Top of plateau near old meteorological station. Level site.
25 cm brownish-grey silt loam, fine to medium crumb structure.
Grades into >10 cm light yellow-brown silt loam, rust-mottled, weak nutty structure.
Plant cover *Agrostis capillaris, Holcus lanatus.*

(h) Floor of shallow valley below summit of island, 2° slope.
15 cm pale grey silt loam, medium crumb structure.
Grades into >10 cm very pale grey silt loam, massive structure.
Plant cover *Agrostis capillaris, Poa pratensis, Holcus lanatus.*